ĐẠI HỌC THỦ DẦU MỘT
2009 THU DAU MOT UNIVERSITY

Thu Dau Mot University Journal of Science
ISSN 2615 - 9635
journal homepage: ejs.tdmu.edu.vn

Antidiabetic vegetables presently traded in Sri Lanka's Vavuniya District

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***Article Info**: Received Oct. 11th, 2022, Accepted Nov. 26th,2022, Available online Dec.15th,2022*
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https://doi.org/10.37550/tdmu.EJS/2022.04.363

ABSTRACT

Diabetes affected about 537 million adults aged 20 to 79 in 2021. Higher vegetable intake helps to manage type 2 diabetes mellitus. Thus, this research aimed to recognize and record the vegetable species currently sold in Sri Lanka's Vavuniya District. At least three fieldwork visits were made between January 2019 and January 2022 to each of the Vavuniya District's major market sites, as well as the neighboring vegetable shops and street stalls. Until June 2022, published relevant research papers were searched in the Web of Science, PubMed, and ScienceDirect databases for the recorded vegetable species in this study to assess the antidiabetic scientific proof. This study recognized and recorded 72 vegetable species from 25 families. Consequently, a study of the literature on 65 vegetable species found that most of the vegetable species had in vivo (37%), followed by clinical (15%) and in vitro (14%) scientific evidence, and six antidiabetic active substances were isolated from the analyzed vegetable species. This work establishes the foundation for additional studies on the fruit species traded in Vavuniya District.

***Keywords:** diabetes, Sri Lanka, Vavuniya, vegetables*

1. Introduction

Diabetes is a significant contributor to kidney failure, lower limb amputation, heart attacks, strokes, and blindness. Medication, diet, routine testing, treatment for complications, and exercise can all help cure diabetes and postpone or prevent its effects (World Health Organization, 2022). Diabetes affected about 537 million adults aged 20 to 79 in 2021. The number of diabetics is expected to climb to 643 million by 2030. Three out of every four individuals with diabetes reside in low- and middle-income nations. About one out of two adults (240 million) with diabetes are unidentified. Diabetes was involved in 6.7 million fatalities in 2021 (International Diabetes Federation, 2022). The ninth-leading reason for fatality in 2019 was diabetes. A rise in early diabetes mortality of 5% occurred between 2000 and 2016 (World Health Organization, 2022). Diabetes accounted for at least US$ 966 billion in health costs, accounting for 9% of total adult expenses. Type 1 diabetes impacts around 1.2 million children and teenagers aged 0 to 19. The prevalence of diabetes during pregnancy is 1 in 6 live births (21 million). There is a greater risk of type 2 diabetes among the 541 million adult population (International Diabetes Federation, 2022). Anyway, type 2 diabetes can be avoided or delayed by doing daily exercise, following a nutritious diet, quitting smoking, and keeping a healthy body weight (World Health Organization, 2022).

Vegetables contribute directly to human health since they contain fiber, phytonutrients, and nutrients. Higher vegetable intake helps to manage type 2 diabetes mellitus (Boeing et al., 2012). The antidiabetic activities of several vegetables have been the subject of several study studies. For example, review of antidiabetic fruits, vegetables, beverages, oils and spices commonly consumed in the diet (Beidokhti and Anna, 2017); Food groups in dietary prevention of type 2 diabetes (Basiak-Rasała et al., 2019); Consumption of fruit and vegetables and the risk of type 2 diabetes: a 4-year longitudinal study among Swedish adults (Ahmed et al., 2020); Critical review: vegetables and fruit in the prevention of chronic diseases (Boeing et al., 2012); Farming for Life: Pilot assessment of the impact of medical prescriptions for vegetables on health and food security among Latino adults with type 2 diabetes (York et al., 2020); Critical review: vegetables and fruit in the prevention of chronic diseases (Boeing et al., 2012).

Biomedical treatments and medications are expensive and come with several worse side effects (Webmd, 2022). Hence, finding affordable and natural treatments that have little or no side effects is advantageous for managing diabetes. Thus, this research aimed to recognize and record the vegetable species currently sold in Sri Lanka's Vavuniya District. Afterward, evaluated the degree of the recorded vegetables' scientific antidiabetic effects. This investigation supports the general population to economically and naturally control or stop diabetes by taking antidiabetic vegetable species. Additionally, studying prospective vegetable species might help the researchers find potential antidiabetic effective extracts and phytochemicals.

2. Materials and Method

2.1. The study region

The District of Vavuniya in Sri Lanka's Northern Province served as the study site for this research (Figure 1). In 2012, there were 171,511 residents living in the 1,967 km^2 that make up Vavuniya District (Department of Census and Statistics of Sri Lanka, 2022). The majority of the population is Sri Lankan Tamils followed by, Sinhalese, Sri Lankan Moors, and Indian Tamils. Furthermore, major religion is Hinduism, followed by Christianity, Buddhism, and Islam.

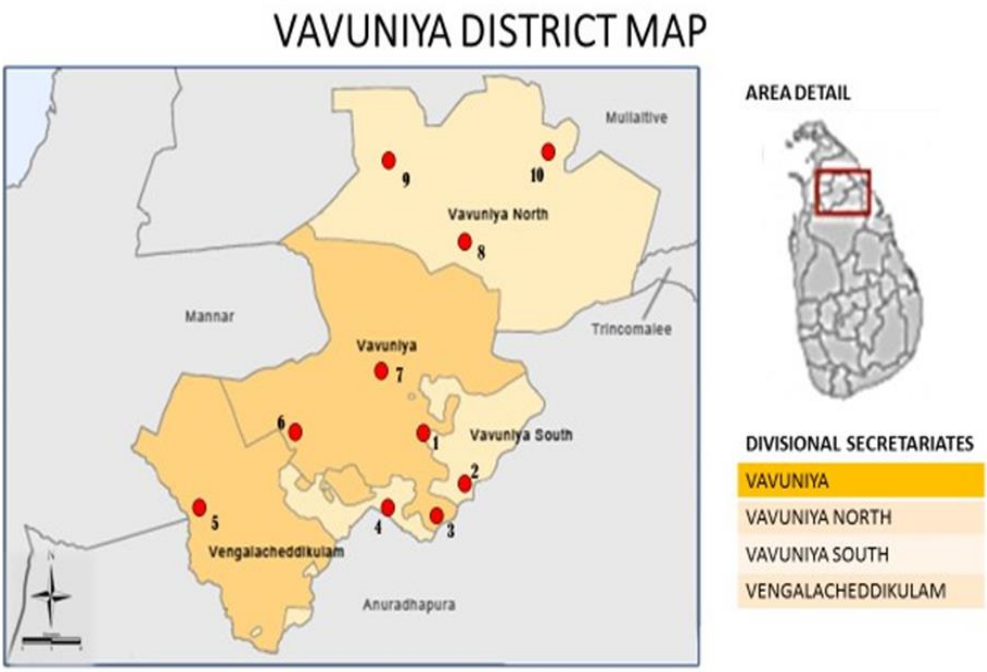

Figure 1. The area of research involves fieldwork on the key marketplaces in the Vavuniya District (Survey Department of Sri Lanka, 2014). 1. Vavuniya Town 2. Mamadu 3. Sithambarapuram 4. Iraperiyakulam 5. Chedikulam 6. Poovarasamkulam 7. Puthukulam 8. Omanthai 9. Kanakarayankulam 10. Nedunkeny.

2.2. Data collection

The time frame for conducting this study was between January 2019 and January 2022. At least three fieldwork visits were made to each of the Vavuniya District's major market sites, as well as the neighboring vegetable shops and street stalls. The authors spent at least two hours visiting each market and the surrounding area. The main markets explored are Cheddikkulam, Iraperiyakulam, Kanakarayankulam, Mamadu, Nedunkeny, Omanthai, Poovarasamkulam, Puthukkulam, Sithamparapuram, and Vavuniya Town.

2.3. Vegetable species identification

Dr. Pholtan Rajamanoharan (Siddha Medicine Teaching Hospital, Jaffna) identified and confirmed every vegetable species sold at each location in Vavuniya District.

2.4. Voucher specimens

Voucher specimens of the selected vegetable species that were locally available were obtained in the Vavuniya District from January 2019 to January 2022. A voucher specimen offers proof for the scientific identification of the biological substance as to which observations and information are collected. Again, Dr. Pholtan Rajamanoharan recognized and confirmed each vegetable species. The Provincial Herbal Garden's herbarium in Trincomalee now houses the voucher specimens. Scientific names and families of the recognized vegetable plant species were verified by the Kew Science (2022) and Global Biodiversity Information Facility (2022) databases.

2.5. Data analysis

The scientific, family, and Tamil names and herbarium voucher (if relevant) specimen numbers of each species of vegetable that was recognized and confirmed during the fieldwork were all recorded (Table 1). Employing previously published publications, they were then compared to plant species used to treat diabetes in Sri Lankan Siddha Medicine. For instance, Vivekanandarajah et al. (2015; 2016; 2017; 2018; 2021a; 2021b; 2021c; 2021d; 2021e; 2021f; 2021g), Rajamanoharan (2014; 2016) and Shanmugalingam et al. (2021). Until June 2022, published relevant research papers were searched in the Web of Science, PubMed, and ScienceDirect databases. Plant species said in the American Herbal Pharmacopoeia-Verified Botanical Reference Materials (2022), World Health Organization Monographs on Selected Medicinal Plants - Volumes 1 to 4 (2004, 2007, 2009, 2017), American Herbal Pharmacopoeia: Botanical Pharmacognosy-Microscopic Characterization of Botanical Medicines (2016), Brendler (2010), and European Medicines Agency's Committee on Herbal Medicinal Products (2022) were considered to have received vast research. Hence, these plant species were removed from the list of articles identifying antidiabetic activities. Each plant species' scientific name was utilized as a search expression. After that, the latest scientific evidence on each plant species' antidiabetic properties were analyzed.

3. Results and Discussion

3.1. Antidiabetic vegetables currently sold

Vavuniya Town market had the most vegetable species, followed by Mamadu, Iraperiyakulam, Kanakarayankulam, Chedikulam, Poovarasamkulam, Puthukulam, Nedunkeny, Sithambarapuram, and Omanthai markets. All the recorded vegetable species in this study are listed in Table 1. Vegetables such as *Abelmoschus esculentus* pods, *Aegle marmelos* flowers, *Allium ampeloprasum* stems, *A. cepa* bulbs and stems, *Allium sativum* bulbs, *Amorphophallus paeoniifolius* rhizomes, *Anethum graveolens* fruits, *Arachis hypogaea* seeds, *Artocarpus altilis* pods, *A. heterophyllus* fruits, *Averrhoa bilimbi* fruits, *Beta vulgaris* rhizomes, *Brassica cretica* flowers, *Capsicum annuum* fruits, *C. frutescens* fruits, *Cocos nucifera* seeds, *Cucurbita maxima* fruits, *C. pepo* fruits, *Curcuma longa* rhizomes, *Daucus carota* rhizomes, *Dioscorea alata* rhizomes, *D. bulbifera* rhizomes, *Donella lanceolata* fruits, *Hibiscus mutabilis* flowers, *Ipomoea batatas* rhizomes, *Lagenaria siceraria* fruits, *Luffa acutangula* fruits, *Mangifera indica* fruits, *M. zeylanica* fruits, *Manihot esculenta* rhizomes, *Momordica charantia* pods, *M. denudata* pods, *Moringa oleifera* pods, *Musa × paradisiaca* fruits and flowers, *Phaseolus lunatus* pods, *P. vulgaris* pods, *Raphanus raphanistrum* rhizomes, *Sesbania grandiflora* flowers, *Solanum lycopersicum* fruits, *S. melongena* pods, *S. torvum* pods, *S. tuberosum* rhizomes, *S. violaceum* fruits, *S. virginianum* pods, *Spondias dulcis* fruits, *Tamarindus indica* fruits, *Trichosanthes cucumerina* fruits, *Vigna radiata* seeds, *Vigna unguiculata* pods, and *Zingiber officinale* rhizomes were obtainable in all markets visited. Also, vegetables such as *Benincasa hispida* fruits, *Brassica oleracea* leaves, *Canavalia ensiformis* pods, *Canna indica* rhizomes, *Careya arborea* flowers, *Coleus rotundifolius* rhizomes, *Cynometra cauliflora* fruits, *Dillenia retusa* fruits, *Ipomoea alba* pods, *Nelumbo nucifera* stems, *Psophocarpus tetragonolobus* pods, and *Solanum rudepannum* vegetable species were available little.

TABLE 1. Vegetable species available at Vavuniya District markets

Scientific name	**Family**	***Tamil***	**Part used**	**Herbarium specimen number**
Abelmoschus esculentus (L.) Moench	*Malvaceae*	வெண்டி *(Vendi)*	Fruit	VS01
Aegle marmelos (L.) Corrêa	*Rutaceae*	வில்வை *(Vilvai)*	Flower	VS02
Allium ampeloprasum L.	*Amaryllidaceae*	இலீக்சு *(Ileekksu)*	Stem	NA
Allium cepa L.	*Amaryllidaceae*	வெங்காயம் *(Venkayam)*	Bulb, Stem	VS03
Allium sativum L.	*Amaryllidaceae*	உள்ளி *(Ulli)*	Bulb	NA
Amorphophallus paeoniifolius (Dennst.) Nicolson	*Araceae*	கருணை *(Karunai)*	Rhizome	VS04
Anethum graveolens L.	*Apiaceae*	சதகுப்பை *(Sathakuppai)*	Fruit	NA
Arachis hypogaea L.	*Fabaceae*	நிலக்கடலை *(Nilakadalai)*	Seed	NA
Artocarpus altilis (Parkinson) Fosberg	*Moraceae*	ஈரப்பலா *(Eerappalaa)*	Fruit	VS05
Artocarpus heterophyllus Lam.	*Moraceae*	பலா *(Palaa)*	Fruit	VS06
Averrhoa bilimbi L.	*Oxalidaceae*	விலிம்பி *(Vilimbi)*	Fruit	VS07
Benincasa hispida (Thunb.) Cogn.	*Cucurbitaceae*	நீற்றுப்பூசணி *(Neetruppoosani)*	Fruit	NA
Beta vulgaris L.	*Amaranthaceae*	செங்கிழங்கு *(Sengkilangu)*	Rhizome	NA
Brassica cretica Lam.	*Brassicaceae*	முட்டைக்கோவா *(Muttaikkovaa)*	Flower	NA
Brassica oleracea L.	*Brassicaceae*	கோவா *(Kovaa)*	Leaf	NA

Canavalia ensiformis (L.) DC.	*Fabaceae*	காட்டவரை *(Kaattavarai)*	Pod	VS08
Canna indica L.	*Cannaceae*	கல்வாழை *(Kalvaalai)*	Rhizome	VS09
Capsicum annuum L.	*Solanaceae*	மிளகாய் *(Milakaai)*	Fruit	VS10
Capsicum frutescens L.	*Solanaceae*	காந்தாரிமிளகாய் *(Kaanthaarimilahaai)*	Fruit	NA
Careya arborea Roxb.	*Lecythidaceae*	கசட்டி *(Kasatti)*	Flower, Fruit	NA
Coccinia grandis (L.) Voigt	*Cucurbitaceae*	கொவ்வை *(Kovvai)*	Fruit	VS11
Cocos nucifera L.	*Arecaceae*	தென்னை *(Thennai)*	Seed	VS12
Coleus rotundifolius (Poir.) A.Chev. & Perrot	*Lamiaceae*	சிறுகிழங்கு *(Sirukilangu)*	Rhizome	NA
Colocasia esculenta (L.) Schott	*Araceae*	சேம்பு *(Sembu)*	Rhizome	VS13
Cucumis anguria L.	*Cucurbitaceae*	பிப்பிஞ்சா *(Pippinjaa)*	Fruit	NA
Cucumis sativus L.	*Cucurbitaceae*	வெள்ளரி *(Vellari)*	Fruit	VS14
Cucurbita maxima Duchesne	*Cucurbitaceae*	பூசணி *(Poosani)*	Fruit	VS15
Cucurbita pepo L.	*Cucurbitaceae*	துபாய்ப் பூசணி *(Dubai Poosani)*	Fruit	NA
Curcuma longa L.	*Zingiberaceae*	மஞ்சள் *(Manjal)*	Rhizome	VS16
Cynometra cauliflora L.	*Fabaceae*	நமிநம் *(Naminam)*	Fruit	NA
Daucus carota L.	*Apiaceae*	செம்மஞ்சட்கிழங்கு *(Semmanjatkilangu)*	Root	NA
Dillenia retusa Thunb.	*Dilleniaceae*	நாய்த்தேக்கு *(Naaiththekku)*	Fruit	NA
Dioscorea alata L.	*Dioscoreaceae*	இராசவள்ளி *(Iraasavalli)*	Rhizome	VS17
Dioscorea bulbifera L.	*Dioscoreaceae*	மோதகவள்ளி *(Mothagavalli)*	Rhizome	VS18
Dioscorea esculenta (Lour.) Burkill	*Dioscoreaceae*	வள்ளி *(Valli)*	Rhizome	VS19
Dioscorea spicata B.Heyne ex Roth	*Dioscoreaceae*	காவல் *(Kaaval)*	Rhizome	NA
Hibiscus mutabilis L.	*Malvaceae*	செவ்வரத்தை *(Sevvaraththai)*	Flower	VS20
Ipomoea alba L.	*Convolvulaceae*	நகணமுக்கோரை *(Nahanamukkorai)*	Fruit	NA
Ipomoea batatas (L.) Lam.	*Convolvulaceae*	வற்றாளை *(Vattraalai)*	Rhizome	NA
Lagenaria siceraria (Molina) Standl.	*Cucurbitaceae*	சுரை *(Surai)*	Fruit	VS21
Lasia spinosa (L.) Thwaites	*Araceae*	கொயிலை *(Koyilai)*	Stem	VS22
Luffa acutangula (L.) Roxb.	*Cucurbitaceae*	பீர்க்கு *(Peerkku)*	Fruit	VS23
Mangifera indica L.	*Anacardiaceae*	மா *(Maa)*	Fruit	VS24
Mangifera zeylanica (Blume) Hook.f.	*Anacardiaceae*	காட்டு மா *(Kaattu Maa)*	Fruit	VS25
Manihot esculenta Crantz	*Euphorbiaceae*	மரவள்ளி *(Maravalli)*	Rhizome	VS26
Maranta arundinacea L.	*Marantaceae*	அரூட்டு *(Arootttu)*	Rhizome	VS27
Momordica charantia L.	*Cucurbitaceae*	பாகல் *(Paahal)*	Fruit	VS28

Momordica denudata (Thwaites) C.B.Clarke	*Cucurbitaceae*	குருவிப்பாகல் *(Kuruvippaahal)*	Fruit	VS29
Momordica dioica Roxb. ex Willd.	*Cucurbitaceae*	தும்பை *(Thumbai)*	Fruit	VS30
Moringa oleifera Lam.	*Moringaceae*	முருங்கை *(Murungai)*	Fruit	VS31
Musa × paradisiaca L.	*Musaceae*	வாழை *(Vaalai)*	Flower, Fruit	VS32
Nelumbo nucifera Gaertn.	*Nelumbonaceae*	தாமரை *(Thaamarai)*	Stem	NA
Phaseolus lunatus L.	*Fabaceae*	சீமை போஞ்சி *(Seemai Ponji)*	Pod	NA
Phaseolus vulgaris L.	*Fabaceae*	போஞ்சி *(Ponji)*	Pod	VS33
Psophocarpus tetragonolobus (L.) DC.	*Fabaceae*	சிறகவரை *(Sirahavarai)*	Pod	VS34
Raphanus raphanistrum L.	*Brassicaceae*	முள்ளங்கி *(Mullangi)*	Rhizome	NA
Sesbania grandiflora (L.) Poir.	*Fabaceae*	அகத்தி *(Ahaththi)*	Flower	VS35
Sicyos edulis Jacq.	*Cucurbitaceae*	மேரம் *(Meram)*	Fruit	NA
Solanum lycopersicum L.	*Solanaceae*	தக்காளி *(Thakkaali)*	Fruit	VS36
Solanum melongena L.	*Solanaceae*	கத்தரி *(Kaththari)*	Fruit	VS37
Solanum rude-pannum Dunal	*Solanaceae*	கறிமுள்ளி *(Karimulli)*	Fruit	NA
Solanum torvum Sw.	*Solanaceae*	சுண்டை *(Sundai)*	Fruit	VS38
Solanum tuberosum L.	*Solanaceae*	உருளை *(Urulai)*	Rhizome	NA
Solanum violaceum Ortega	*Solanaceae*	முட்சுண்டை *(Mutsundai)*	Fruit	NA
Solanum virginianum L.	*Solanaceae*	கண்டங்கத்தரி *(Kandangkaththari)*	Pod	VS39
Spondias dulcis Parkinson	*Anacardiaceae*	அம்பிரலா *(Ambiralaa)*	Fruit	VS40
Tamarindus indica L.	*Fabaceae*	புளி *(Puli)*	Fruit	VS41
Trichosanthes cucumerina L.	*Cucurbitaceae*	புடோல் *(Pudol)*	Fruit	VS42
Vicia faba L.	*Fabaceae*	அவரை *(Avarai)*	Pod	VS43
Vigna radiata (L.) R.Wilczek	*Fabaceae*	பாசிப்பயறு *(Paasippayaru)*	Seed	NA
Vigna unguiculata (L.) Walp.	*Fabaceae*	தட்டைப்பயறு *(Thattaippayaru)*	Pod, Seed	NA
Zingiber officinale Roscoe	*Zingiberaceae*	இஞ்சி *(Inji)*	Rhizome	VS44

This study recognized and recorded 72 vegetable species from 25 families (Table 1). *Solanum* is the genus that contains most of the vegetables, followed by *Dioscorea, Allium,* and *Momordica*. The *Cucurbitaceae* family contributed the greatest of the vegetable species, followed by the *Fabaceae, Solanaceae, Dioscoreaceae, Amaryllidaceae, Anacardiaceae, Araceae,* and *Brassicaceae* families. The plant part that is sold the most is the fruit, followed by the rhizome, flower, seed, stem, bulb, and root. In Sri Lankan Siddha Medicine's antidiabetic preparations, 18 vegetable species (or 25%) are utilized including *Aegle marmelos, Allium sativum, Anethum graveolens, Artocarpus heterophyllus, Averrhoa bilimbi, Cocos nucifera, Curcuma longa, Momordica charantia,* *Moringa oleifera*, *Musa × paradisiaca*, *Nelumbo nucifera, Sesbania grandiflora. Solanum rude-pannum, Solanum virginianum, Spondias dulcis, Tamarindus indica*, *Vigna radiata*, and *Zingiber officinale.*

3.2. Levels of recognized vegetable species' scientific evidence

Seven vegetable species have been extensively researched and are found worldwide. Consequently, a study of the literature on 65 vegetable species found that 43 of them (or 66%) contain antidiabetic scientific proof. Six antidiabetic active substances have been isolated from the analyzed vegetable species. Based on the greatest level of antidiabetic scientific evidence that is now obtainable for the selected vegetable species, three levels of scientific proof were developed, and they were as follows:

1. Vegetable species had *in vitro* (external to the live organism and in an artificial setting) antidiabetic scientific proof.

2. Vegetable species had *in vivo* (in an animal or plant's live body) antidiabetic scientific proof.

3. Vegetable species had clinical antidiabetic scientific proof.

3.2.1. Vegetable species had in vitro antidiabetic scientific proof

Nine vegetable species (or 14%) contained singly *in vitro* antidiabetic proof (Table 2). For example, *Artocarpus altilis, Lasia spinosa, Manihot esculenta, Psophocarpus tetragonolobus*, *Raphanus raphanistrum*, *Spondias dulcis*, *Trichosanthes cucumerina*, and *Vigna unguiculata*. Hitherto, no antidiabetic compound was detected from these vegetable species.

TABLE 2. Vegetable species have *in vitro* scientific proof

Scientific name	Level of scientific evidence	Part	Extract / compound	Assay	Reference
Artocarpus altilis (Parkinson) Fosberg	*In vitro*	Fruit	Aqueous	α-Glucosidase inhibitory	Sairam and Urooj, 2012
Artocarpus altilis (Parkinson) Fosberg	*In vitro*	Fruit	Aqueous	α-Amylase inhibitory	Sairam and Urooj, 2012
Artocarpus altilis (Parkinson) Fosberg	*In vitro*	Fruit	Aqueous	Yeast cell	Sairam and Urooj, 2012
Lasia spinosa (L.) Thwaites	*In vitro*	Stem	Ethanol	α-Amylase inhibitory	Men et al., 2021
Lasia spinosa (L.) Thwaites	*In vitro*	Stem	Ethanol	α-Glucosidase inhibitory	Men et al., 2021
Manihot esculenta Crantz	*In vitro*	Rhizome	Not stated	α-Amylase inhibitory	Adefegha et al., 2021
Manihot esculenta Crantz	*In vitro*	Rhizome	Not stated	α-Glucosidase inhibitory	Adefegha et al., 2021

Manihot esculenta Crantz	*In vitro*	Rhizome	Not stated	α-Amylase inhibitory	Khusniati et al., 2019
Psophocarpus tetragonolobus (L.) DC.	*In vitro*	Pod	Ethanol	α-Amylase inhibitory	Suttisansanee et al., 2021
Psophocarpus tetragonolobus (L.) DC.	*In vitro*	Pod	Ethanol	α-Glucosidase inhibitory	Suttisansanee et al., 2021
Raphanus raphanistrum L.	*In vitro*	Rhizome	Not applicable	α-Amylase inhibitory	Hussein et al., 2020
Spondias dulcis Parkinson	*In vitro*	Fruit	Ethanol	α-Amylase inhibitory	Hossain et al., 2008
Spondias dulcis Parkinson	*In vitro*	Fruit	Ethanol	α-Glucosidase inhibitory	Mohamed Yunus et al., 2021
Spondias dulcis Parkinson	*In vitro*	Fruit	Ethanol	α-Glucosidase inhibitory	Hossain et al., 2008
Trichosanthes cucumerina L.	*In vitro*	Fruit	Aqueous	Antiglycation	Sathishkumar et al., 2015
Vigna unguiculata (L.) Walp.	*In vitro*	Seed	Methanol	α-Amylase inhibitory	Irondi et al., 2019
Vigna unguiculata (L.) Walp.	*In vitro*	Seed	Methanol	α-Glucosidase inhibitory	Irondi et al., 2019

3.2.2. Vegetable species had in vivo antidiabetic scientific proof

Table 3 provides a list of vegetable species with *in vivo* antidiabetic investigations. The *in vivo* antidiabetic evidence was present in the majority (37%) of the recorded vegetable species. *Momordica dioica* had the most evidence (Jha et al., 2019; Rao and Mohan, 2014; Sharma and Singh, 2014; Jain et al., 2014; Ilango et al., 2009; Singh et al., 2011)

The largest number of antidiabetic chemicals also discovered in vegetable species have *in vivo* proof. Falcarinol and Falcarindiol were isolated from *Daucus carota*, Flazin was isolated from *Solanum lycopersicum*, and Methyl 3,4,5-trihydroxycinnamate was isolated from *Solanum torvum* (El-Houri et al., 2014; Seong et al., 2021; Takahashi et al., 2010)

TABLE 3. Vegetable species have *in vivo* scientific proof

Scientific name	Part	Extract / compound	Model	Reference
Aegle marmelos (L.) Corrêa	Flower	Aqueous	Alloxan-induced diabetic	Kumari et al., 2013
Allium ampeloprasum L.	Stem	Ethanol	Not stated	Sedighi M et al., 2012
Amorphophallus paeoniifolius (Dennst.) Nicolson	Rhizome	Not stated	Alloxan-induced diabetic	Rahman et al., 2021
Averrhoa bilimbi L.	Fruit	Aqueous	Streptozotocin-induced diabetic	Kurup and Mini, 2016
Averrhoa bilimbi L.	Fruit	Aqueous	Streptozotocin-	Kurup and

			induced diabetic	Mini, 2017
Benincasa hispida (Thunb.) Cogn.	Fruit	Petroleum ether	Alloxan-induced diabetic	Mishra and Barik, 2009
Benincasa hispida (Thunb.) Cogn.	Fruit	Ethanol	Alloxan-induced diabetic	Patil et al., 2010
Benincasa hispida (Thunb.) Cogn.	Fruit	Chloroform	Alloxan-induced diabetic	Patil et al., 2011
Canna indica L.	Rhizome	Ethanol	Caffeine-Nicotine-induced type 2 diabetic	Kumbhar et al., 2017
Capsicum annuum L.	Fruit	Ethanol	Streptozotocin-induced diabetic	Mohammed et al., 2017
Coccinia grandis (L.) Voigt	Fruit	Ethanol	Alloxan-induced diabetic	Ramakrishnan et al., 2011
Coccinia grandis (L.) Voigt	Fruit	Chloroform	Nicotinamide-Streptozotocin-induced diabetic	Kaushik et al., 2017
Cucumis sativus L.	Fruit	Ethanol	Streptozotocin-induced diabetic	Karthiyayini et al., 2009
Cucumis sativus L.	Fruit	Kaempferol	Alloxan-induced diabetic	Ibitoye et al., 2018
Cucumis sativus L.	Fruit	Aqueous	Oxidative stress	Heidari et al., 2016
Cucumis sativus L.	Fruit	Aqueous	Carbonyl stress	Heidari et al., 2016
Cucumis sativus L.	Fruit	Ethanol	Alloxan-induced diabetic	Alkofahi et al., 2017
Cucurbita pepo L.	Fruit	Ethanol	Alloxan-induced diabetic	Dixit and Kar, 2010
Cucurbita pepo L.	Fruit	Aqueous	Alloxan-induced diabetic	Thanh et al., 2021
Cucurbita pepo L.	Fruit	Not applicable	Alloxan-induced diabetic	Sedigheh et al., 2011
Cucurbita pepo L.	Fruit	Not applicable	Streptozotocin-induced diabetic	Sayahi and Shirali, 2018
Cucurbita pepo L.	Fruit	Ethanol	Alloxan-induced diabetic	Alkofahi et al., 2017
Cynometra cauliflora L.	Leaf	Ethanol	C57BL/6 obese mice	Seyedan et al., 2019
Cynometra cauliflora L.	Leaf	Vitexin	C57BL/6 obese mice	Seyedan et al., 2019
Dioscorea alata L.	Rhizome	Ethanol	Alloxan-induced diabetic	Maithili et al., 2011
Dioscorea alata L.	Rhizome	Ethanol	Alloxan-induced diabetic	Estiasih et al., 2013
Dioscorea alata L.	Rhizome	Not applicable	Not stated	Adeloye et al., 2021
Dioscorea bulbifera L.	Rhizome	Aqueous	Streptozotocin-induced diabetic	Ahmed et al., 2009

Ipomoea batatas (L.) Lam.	Rhizome	Not applicable	Streptozotocin-induced diabetic	Ogasawara et al., 2011
Ipomoea batatas (L.) Lam.	Rhizome	Aqueous	Streptozotocin-induced diabetic	Kusano et al., 2001
Ipomoea batatas (L.) Lam.	Rhizome	Aqueous	Yellow KK	Kusano et al., 2001
Ipomoea batatas (L.) Lam.	Rhizome	Aqueous	db/db	Kusano et al., 2001
Ipomoea batatas (L.) Lam.	Rhizome	Aqueous	Zucker fatty	Kusano et al., 2001
Ipomoea batatas (L.) Lam.	Rhizome	Not applicable	Nicotinamide-Streptozotocin-induced diabetic	Shih et al., 2020
Ipomoea batatas (L.) Lam.	Rhizome	Cyanidin 3-caffeoyl-p-hydroxybenzoylsophoroside-5-glucoside	Not stated	Jang et al., 2019
Luffa acutangula (L.) Roxb.	Fruit	Methanol	Streptozotocin-induced diabetic	Pimple et al., 2011
Luffa acutangula (L.) Roxb.	Fruit	Methanol	Glucose loaded	Jani and Goswami, 2017
Momordica dioica Roxb. ex Willd.	Fruit	Aqueous	Alloxan-induced diabetic	Sharma and Singh, 2014
Momordica dioica Roxb. ex Willd.	Seed	Chloroform	Streptozotocin-induced diabetic	Rao and Mohan, 2014
Momordica dioica Roxb. ex Willd.	Seed	Ethyl acetate	Streptozotocin-induced diabetic	Rao and Mohan, 2014
Momordica dioica Roxb. ex Willd.	Fruit	Methanol	Streptozotocin-induced diabetic	Gupta et al., 2011
Momordica dioica Roxb. ex Willd.	Fruit	Aqueous	Alloxan-induced diabetic	Singh et al., 2011
Momordica dioica Roxb. ex Willd.	Fruit	Not applicable	Normal	Fernandopulle et al., 1994
Momordica dioica Roxb. ex Willd.	Fruit	Hexane	Alloxan-induced diabetic	Ilango et al., 2009
Momordica dioica Roxb. ex Willd.	Fruit	Methanol	Alloxan-induced diabetic	Ilango et al., 2009
Momordica dioica Roxb. ex Willd.	Fruit	Not stated	Not stated	Samaddar et al., 2020
Momordica dioica Roxb. ex Willd.	Fruit	Not applicable	Streptozotocin-induced diabetic	Poovitha et al., 2017
Momordica dioica Roxb. ex Willd.	Seed	Methanol	Streptozotocin-induced diabetic	Rao et al, 2016
Momordica dioica Roxb. ex Willd.	Fruit	Ethanol	Streptozotocin-induced diabetic	Jain et al., 2014

Momordica dioica Roxb. ex Willd.	Fruit	Methanol	Streptozotocin-induced diabetic	Jha et al., 2019
Momordica dioica Roxb. ex Willd.	Fruit	Methanol	Nicotinamide-Streptozotocin-induced diabetic	Rathee and Kamboj, 2017
Phaseolus vulgaris L.	Pod	Aqueous	Streptozotocin-induced diabetic	Almuaigel et al., 2017
Phaseolus vulgaris L.	Pod	Aqueous	Streptozotocin-induced diabetic	Kyznetsova et al., 2015
Phaseolus vulgaris L.	Pod	Aqueous	Streptozotocin-induced diabetic	Halenova et al., 2019
Phaseolus vulgaris L.	Pod	Aqueous	Diabetic	Pari and Venkateswaran, 2003
Sesbania grandiflora (L.) Poir.	Flower	Aqueous	Normal	Guillasper et al., 2020
Sesbania grandiflora (L.) Poir.	Flower	Petroleum ether	Streptozotocin-induced diabetic	Sureka et al., 2021
Solanum lycopersicum L.	Fruit	Not stated	Type 2 diabetic	Firani et al., 2018
Solanum lycopersicum L.	Seed	Essential oil	Streptozotocin-induced diabetic	Saftencu et al., 2019
Solanum melongena L.	Fruit	Ethanol	Hypercholesterolemia-diabetic	Tandi et al., 2019
Solanum melongena L.	Fruit	Methanol	Not stated	Jani and Goswami, 2017
Solanum torvum Sw.	Fruit	Methanol	Alloxan-induced diabetic	Vasuki and Hari, 2014
Solanum torvum Sw.	Fruit	Methyl caffeate	Streptozotocin-induced diabetic	Gandhi et al., 2011
Tamarindus indica L.	Fruit	Methanol	Glucose-induced diabetic	Roy et al., 2010
Vicia faba L.	Pod	Not stated	Alloxan-induced diabetic	Mejri et al., 2018
Vigna radiata (L.) R.Wilczek	Seed	Not stated	Alloxan-induced diabetic	Yeap et al., 2012
Vigna radiata (L.) R.Wilczek	Seed	Not applicable	Not stated	Liyanage et al., 2018

3.2.3. Vegetable species had clinical antidiabetic scientific proof

Nearly 15% of the vegetable species had clinically proven antidiabetic properties. Most investigations were conducted on *Abelmoschus esculentus*, *Anethum graveolens*, and *Musa × paradisiaca* (Haryati et al., 2019; Moradi et al., 2020; Islas et al., 2005; Haidari et al., 2020; Mobasseri et al., 2014; Rao et al., 2021; Nedic et al., 2012; Chaiyasit et al., 2009; Mahmoodpoor et al., 2018; Katare et al., 2013; Evans et al., 2014; Lintas et al., 1995; Edo et al., 2011).

Two antidiabetic compounds were identified and Kaempferol 3-O-α-l-rhamnopyranosyl (1→6)-β-d-glucopyranosyl(1→2)-β-d-galactopyranosyl-7-O-[3-O-o-anisoyl]-α-l-rhamnopyranoside was isolated from *Canavalia ensiformis* (Sutedja et al., 2020). Further, Isoquercetin was isolated from *Lagenaria siceraria* (Ningsih et al., 2020). Both compounds showed antidiabetic effects in *in vitro* assays.

TABLE 4. Vegetable species have clinical scientific proof

Scientific name	Part	Extract	Human subject	Reference
Abelmoschus esculentus (L.) Moench	Fruit	Aqueous	Type 2 diabetic	Haryati et al., 2019
Abelmoschus esculentus (L.) Moench	Fruit	Not applicable	Type 2 diabetic	Moradi et al., 2020
Allium cepa L.	Bulb	Raw	Type 2 diabetic	Islas et al., 2005
Anethum graveolens L.	Fruit	Not applicable	Type 2 diabetic	Haidari et al., 2020
Anethum graveolens L.	Fruit	Not applicable	Type 2 diabetic	Mobasseri et al., 2014
Artocarpus heterophyllus Lam.	Fruit	Not applicable	Type 2 diabetic	Rao et al., 2021
Canavalia ensiformis (L.) DC.	Pod	Not stated	Diabetic	Nedić et al., 2012
Capsicum frutescens L.	Fruit	Capsaicin	Normal	Chaiyasit et al., 2009
Cucurbita maxima Duchesne	Fruit	Not applicable	Diabetic	Mahmoodpoor et al., 2018
Lagenaria siceraria (Molina) Standl.	Fruit	Not applicable	Type 2 diabetic	Katare et al., 2013
Mangifera indica L.	Fruit	Not applicable	Obese	Evans et al., 2014
Musa × *paradisiaca* L.	Fruit	Not applicable	Normal	Lintas et al., 1995
Musa × *paradisiaca* L.	Fruit	Not applicable	Type 1 diabetic	Lintas et al., 1995
Musa × *paradisiaca* L.	Fruit	Not applicable	Type 2 diabetic	Edo et al., 2011

6. Conclusion

Vegetables are an essential element of our everyday diet. Around 34% of the recorded vegetable species in this study had no antidiabetic scientific data. As a result, additional research is required to assess the antidiabetic properties of these vegetables. Also, in this additional research, the emphasis should be given to commonly found vegetable species. As a result, these vegetable species will be beneficial for diabetes management with minimal side effects and at a lower cost. Vegetables that are easily obtainable can also be more widely available and cheap. Several antidiabetic active compounds were discovered in the vegetable species investigated in this research. As a result, more studies should be conducted to analyze these chemicals in more sophisticated models so as to gather more scientific proof. This study discovered, recorded, and analyzed the antidiabetic properties of vegetable species marketed in Sri Lanka's Vavuniya District. This work establishes the foundation for additional studies on the fruit species traded in Vavuniya District.

Conflict of interest

The authors declare that there is no conflict of interest.

Acknowledgments

This work received no funding. The authors are grateful to their family members for their support in delivering this work.

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